LECTURE SERIES

Mobile Ubiquitous Network Environment

1

Zhang Ping, Ji Yang, Feng Zhiyong

(Research Center for Wireless New Technology, Beijing University of Posts and Telecommunications, Beijing 100876, China)

The Mobile Ubiquitous Service Environment (MUSE), established through the coordination and integration of mobile telecommunications and ubiquitous network in the pursuit of Always Best Experience (ABE), represents the major development trend for the next generation mobile wireless network. Research on MUSE will involve the integration of computing model system, service platform system, operating system and terminal structure system, all of which involve exploration and innovation of new networking structure, its control and management as well as way of measuring. The change in network resources triggers the change in network computing models. To make readers have a basic understanding of mobile ubiquitous network environment, this lecture will introduce MUSE in two sections. The first section describes the background of MUSE and its future development prospect. The second section focuses on the design principles and key technologies in MUSE model, which make services realized, as well as the networking structure of MUSE model, and the key technologies and design principles of networking.

The current society is witnessing great changes brought to us by the information revolution. Information network technologies, represented by mobile telecommunications, fixed telecommunications, personal computers and Internet, have successfully achieved a great development in the past 20 years. This information revolution has entered all social sectors such as industry, agriculture, commerce, culture, education, public service and social security, changing the ways of life and people's thinking. Among those technologies, the mobile telecommunications is quite eye-catching for its wide application in people's life.

For its convenience, flexibility, and its integration with Internet in some new industrial value chains, mobile telecommunications has become one of the most robust and dynamic areas for innovation.

It is noticeable that in the recent ten years the mobile telecommunication has been progressed from 2G to 3G. During this progress, numerous wireless technologies surfaced, such as GSM, CDMA, PHS, WCDMA, CDMA2000, TD-SCDMA, WiMAX, 802.11a/b/g, UWB, DVB-S/T/H, MMDS, LMDS, Bluetooth, ZigBee, RFID, and more. Most countries have already been working on the new transmitting technologies, such as Super3G and Beyond3G. Obviously, the heterogeneous features in future networks will be certainly more outstanding. In fact, not only does this trend of more heterogeneity, diversity and ubiquity exist in the field of wireless access, but also it does in the fields such as terminal, networking and service platform technologies.

Diversity and heterogeneity in networks make people puzzled about the future trend of technological development. Therefore, the World Wireless Research Forum (WWRF) established a Prospect Committee, which is specially working on future prospects in the hope to figure out questions. These questions are as "what kind of services can future wireless telecommunications generate?, "what kind of services do we need and what technologies are relatively more important in the future?", "what are the challenges in realizing these services?", through concerted discussions. The discussions are not confined to transmitting any more, but involving the future operating model of the entire information system. The Mobile Ubiquitous Service Environment (MUSE) was first introduced in the WWRF Beijing Conference in 2004, as a tentative description of the future prospects of the wireless world.

The MUSE model the service supporting ability of networks and terminals, and unifies the two to a ubiquitous service environment that can provide personalized services and could be universally sensible and strongly adaptable.

The goal of Always Best Experience (ABE) that MUSE pursues emphasizes that when user's environment and conditions change, it can still provide diversified services in an intelligent way and these services can adapt to new changes automatically. Moreover, MUSE desires to obtain abundant and diversified new services by means of concerted and coordinated work not only within heterogeneous networks but also between personal networks and service-providers' networks. Fundamental problems are exposed in the current IP network operating process. Particularly, the problems to be resolved are inadequate control over network,

inefficient utilization of network resources, difficulties in inter-connection among existing heterogeneous networks, and network integration and seamless transfer of different services in the future mobile Internet environment.

In an effort of resolving the series of fundamental problems mentioned above, we carried out research on MUSE. The research is focusing on how to construct a network system structure that can achieve coordinated work and sound resources distribution on premises of being controllable and manageable.

As a structure model for the future information network, the MUSE is dedicated to realizing highly efficient information interaction between machines, machine and human, human and real environment. It allows different information technologies to be integrated into social lives through new services. This process is improving the information transmission model in aspects of information collection, transmission, transaction to reaction, and more. It is also raising the human society's comprehensive productivity through the improvement of efficiency, in order to meet the needs of the future society in the field of information intelligence.

1 The Current Development of MUSE

In 1991, Mark Weiser, the chief scientist of Xerox PARC set forth the idea of "Ubiquitous Computing" as a contrast to the design idea of "letting computer become the focus of human attention". The idea of "Ubiquitous Computing" was stressing to make computer part of environment an ordinary daily tool and let computer stay away from people's eye focus, since people's attention should go back to the tasks that they are supposed to accomplish.

The idea of ubiquitous computing has aroused unceasing debates in the academic circle and the industry since it was set forth. As far as network system is concerned, ubiquity means diversified network and equipment, and wide application of wireless telecommunications technologies, thus leading to abundant forms of network structures. The issue of telecommunications is always closely related to environment. The ubiquitous micro equipment environment featuring short distance, low power and low computing ability surely brings the underline cause for networking technology innovation. For example, some scientists thought that the traditional Transport Control Protocol/ Internet Protocol (TCP/IP) was not economical in network conditions of extremely limited resources as micro wireless sensors. For this reason, it is suggested that some networking and transmission protocols be used in a small area, like NanoIP. The "invisible" in the idea of ubiquitous computing is likely to cause far-reaching transformation to networking system structure. For instance, pursuit for faster speed, some scientists proposed that ubiquitous telecommunications network structure should carry out processing based on data rather than identifier to achieve control over automatic network routing which is invisible to human. Before the year 2000, although some importance had been attached to wireless telecommunications in terms of research on ubiquitous network, examinations into wireless network's flexibility was still not fully carried out. After all, only in recent years short-distance technologies are coming out one after another and multimedia IP technologies in fixed cellular mobile network begin to thrive.

Thanks to the rapid development of such technologies as micro-electronics and low-power wireless telecommunications, breakthrough in hardware technologies required by ubiquitous computing is no longer far away. Most scientists in different countries believe that an era of ambient intelligence is coming nearer to us. Ambient intelligence, established in the Information Society Technology (IST) project of the Sixth Framework Program (FP6) of the European Union (EU) as a major topic for research, aims at exploring problems that might pop up when ambient intelligent environment is being achieved through information infrastructure. After nearly a decade's development of information society, Japan has set forth "Ubiquitous Japan", the new development objective of which is to replace the previous goal of "E-Japan", and has carried out a series of research programs to develop a blueprint for the future ubiquitous information society. The International Code Council (ICC) has set "Towards Ubiquitous Era" as the main theme of its 2005 International Academic Meeting. All these developments are indicating that the whole society has attached unprecedented significance to ambient intelligence. People are becoming increasingly dissatisfied with the simple discussion of technical problems in a confined small scale, wishing to draw out a whole prospect for future "Ambient Intelligent Era". The deliberations to the problems in a number of aspects, such as social needs, service application, science and technology, as well as systemized research on numerous problems that might occur, are the wishes of the people.

Presently, the concept of "Total IP Network" makes people firmly believe that the dominant trend for future network development must be the integration and evolution of networks based on IP core network. With IP network's flexibility and ability to provide all Internet services, the IP network will evolve towards the Next Generation Internet (NGI). Meanwhile, it should have the high stability, reliability and manageability of the telecommunications network, and can automatically deploy the entire network resources according to the operators' service design requirements. With new value-added integrated service modules, the manageable IP network will further develop towards the Next Generation Network (NGN).

The NGN adopts the manageable IP network structure based on the Service Level Agreement (SLA) to meet service providers' demands to control and manage IP network resources. It supports universal mobility to guarantee seamless roaming and services in different networks. In addition, it adopts open Application Programming Interface (API) to separate services and networks, therefore it can provide services flexibly. All these ideas have profound guiding implications to future network design.

In the mobile telecommunications sector, we can clearly feel the development trend to a total IP network and its ability to provide more customized services of 3GPP's evolution

from Release 5 to Release 6 and to Release 7. The goal of Release 5 is to construct a total IP mobile network, that is, to use IP to have all the audio, data and multimedia services fulfilled and well controlled. At the same time Release 6 and Release 7 concentrate on strengthening services and improving the IP network's interconnection to other networks. The mobile telecommunications sector has experienced a rather vigorous development worldwide. People are trying to make further efforts to design future model for the next generation mobile Internet based on the integration of wireless telecommunications system and Internet described by 3GPP's Release 5/6/7.

Some researches have been made to portray a prospective blueprint. The EU set forth the concept of "I-centric" in 2002, advocating Cyberspace, which laid priority on human. Japan proposed the idea of "Flying-Carpet", anticipating possible future services from a professional perspective.

The MUSE in this article starts from a professional perspective, holding that service demands will surely promote the integration of Wide Area Network (WAN) represented by mobile telecommunications network and ubiquitous computing. Accordingly, it is evolving into a network with different structures but being able to work in coordination, which, with its ubiquitous flexible computing ability, brings people and their ambient devices closer in more harmonious relationship.

The MUSE has gained widespread acknowledgement and attention at home and abroad, it has won attention from enterprises as China Mobile, Telecommunications Research Center under the Ministry of Information Industry, ZTE, Lenovo, and others. The China Communications Standard Association (CCSA) made a decision in its 2004 session that it would formally raise a proposition to International Telecommunications Union (ITU) in 2005 to take MUSE as the future objective.

The issue of network system structure is the core issue of the future prospect, and related studies have gained wide attention. The EU IST program is the most typical research of this kind on the globe.

The EU IST program has made systemized research plans to ubiquitous intelligence and coordination among heterogeneous networks, and has set up more than 20 large-scale projects under the B3G Framework in order to make the research comprehensive. The concept of "Ambient Control Space" raised in the project of "Ambient Networks" actually proposed a cross-domain joint control model. It explained the possible influence that the concept of managing the entire network with coordination might cause to protocol structure design. It is one of the focuses of present researches.

The concept of Personal Network (PN) rose in the MAGNET project in 2004 suggested to include all devices and networks in Personal Area Network (PAN), Wide Area Network (WAN) and Vehicle Area Network (VAN) into the category of PN and have the telecommunications services optimized, which was a new idea. The INSTINCT project studies coordination between Digital Video Broadcasting (DVB) network and Wideband Code Division Multiple Access (WCDMA) network in multimedia services, demonstrating the possible mutually supplementary features among different heterogeneous WANs. The successful commercial utilization of DVB in Europe makes this project more noticeable. The E2R project improved Software Define Radio (SDR) technology, putting its focus on how networks support reconfiguration technology in a terminal to terminal situation. Besides, other projects such as WINNER, MOBDICK and ANWIRE, all have made meaningful tentative researches on heterogeneous network from different layers and perspectives.

To further strengthen coordination and cooperation in researches, better publicize research results and promote world researches in related fields, the Wireless World Research Forum (WWRF) was established on the initiative of the EU. These EU programs raised a lot of seference-worthy ideas in commercial application, industrial chain planning, and technological innovation, with more focus on technological innovation and prospects of industrialization in a comprehensive point of view. Each program shows a certain innovation area. Therefore, many innovations are seen in a number of areas, through which we can see the broad space for innovation on the issue of coordination between heterogeneous networks.

2 Driving Forces of Network Development

2.1 Social Demand

The human society's great demand for mobile telecommunications has been well proved through the rapid development of the mobile telecommunications industry in the past several decades. Meanwhile, mobile telecommunications is changing people's ways of living. The advent of such new words as Mobile Life, Mobile Internet and Mobile City, shows that mobile telecommunications has penetrated into many social sectors. It breaks the limit of time and space in information exchange and enormously increases the frequency of information exchanges, consequently, accelerates the social pace and brings high working efficiency for all social actors.

The pursuit of higher efficiency will remain as the necessary demand of the future society to gradually improve its self-development. The improvement of information technologies obviously has direct influence on the entire social efficiency, but in the future the model of influence will be more advanced. Currently, utilization of different telecommunications tools improves people's ability to obtain information resources which causes the working efficiency increases.

The abundance of communication tools and information resources in the future makes it difficult to find the effective way to obtain useful information. Therefore, people need cooperative and coordinated telecommunication and information tools to help accomplish different tasks efficiently. That is, an integrated information environment with various tools working together can voluntarily provide such services to people. In the future society, new services will come out with the cooperation and coordination of different ubiquitous intelligent equipments, such as sensor network and mobile telecommunication network. If the advent

and popularization of this new model can make the society's internal information exchange and decision making process more efficient, it will gradually obtain advantages in competition and become the mainstream of future development.

2.2 Industrial Demand

From the second generation to the third generation, the basic features of the development of mobile telecommunications can be characterized as more services, wider coverage, flexible and efficient network technologies, significant rise in broadband, and diversified terminal functions and categories[7].

However, the industrial development encounters new problems, of which the major one is the heterogeneity of different networks. This problem becomes increasingly prominent with the advancement of technologies because a new and more competitive technology emerges before the old is fully implemented or has recouped the investment. The over-competition of different technology categories results in a rise in the overall risk of the industrial development. One of the most difficult problems that future telecommunications industry must deal with is the bad interconnection and integration performance of networks. This is because innovation is needed even in the process of integrating the previous technologies of the same category, not to mention introducing a new technology category. Besides, for reasons such as operation, investment, or user habit, new technological category is unlikely to replace the old in a short term; therefore, the coexistence of heterogeneous networks is inevitable.

Heterogeneity makes the goal of seamless communication, especially in WAN, hard to achieve. To overcome this problem, multi-model communications should be realized, otherwise a software technology is necessary for configuration of wireless telecommunications networks. In this way, risks in all sections of the telecommunications industrial chain can be lowered and the whole industry can develop steadily.

2.3 Economic Demand

The knowledge and information have already become the core productive factors of the new economy. The informative economy requires that information retrieval must be quick and effective. The future communications system with intelligence can understand users' needs and potential needs, and is prompt in finding useful information, screening useless information and avoiding information deluge.

After agricultural, manufacturing and service economy, we will meet the "Experience in the future" economy. That means "to create a kind of distinctive atmosphere in which services are delivered in a certain pleasant means, and customers are willing to pay for the pleasant and comfortable process of service delivery". In this economic model, enterprises are not only selling things with real shapes, but more accurately, promoting a life style. Similarly, mobile telecommunications future development will surely transform from service economy to experience economy, and what customers enjoy will more be as an experience and a life style, rather than simple telecommunications.

2.4 Service Demands

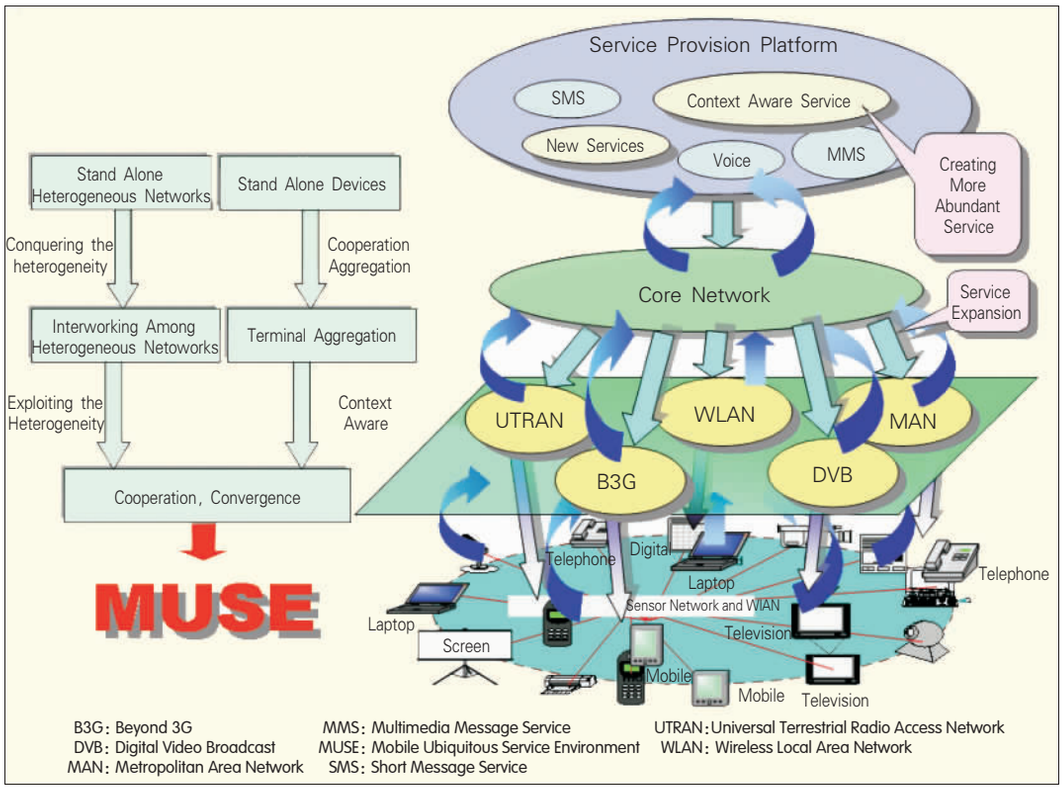
The development of networks technologies and the deployment of information collection terminals both stress on the ability to support rich services. The common problem in Internet and telecommunications networks is the lack to provide intelligent and customized services. In addition, it is difficult to remove the limitations inflicted upon the scope and experience of the services caused by the heterogeneity of the network. The limited deployment of information collection terminals also leads to inadequate information sources. Another reason for monotonous services contents and forms is insufficient integration and finding of information.

Therefore, researches on intelligent service theories and service environment description theories need to be strengthened in the future and future users' application demands need to be studied and abstracted. Full attention needs to be paid to users' subjunctive feeling in the service development and service application process. Considering the intelligent way of service generation and the technological possibilities of developing intelligent services as environment sensing and context sensing, it has become necessary to study and establish an intelligent service theory. At the same time, the future application environment of mobile service is complicated. The network heterogeneity and the terminal intelligent restructuring have brought new characteristics and changes to mobile services. How can network and the abilities of terminals be abstracted to a group of functions and systems? How to make these abilities easy to be sensed, described, quantified and calculated so that a controllable and manageable coordinative work with high efficiency and intelligence can be accomplished? How to integrate all these heterogeneous abilities of networks in different application backgrounds and work out the most suitable quantified model for ABE that best meets users' demands, services demands and the current network conditions? These have become fundamental questions to be researched and answered in the future.

2.5 Network Demands

In the field of network transmission technology, considering people's increasing needs for information and decreasing supply of frequency resources, high speed, high frequency, high efficiency and low cost will always be a demand engine driving technological development. However, in the field of network system structure, factors for change and innovation are much more complicated, bringing to the future networks numerous new characteristics.

It has become a common understanding to base the future networks on IP. But today's IP network is far under the requirement of telecommunications level in terms of manageability. Therefore, a controllable and manageable IP network will be one of the major research subjects in the field of future network development. Since network heterogeneity is inevitable in the future, the seamless interconnection between core network and connected networks will become the development trend of future network from the user experience perspective. At the same time, on the network runner's



▲ Figure 1. Evolution of MUSE.

perspective, what they concern most is the manageability of network operation and high efficiency in utilization of network resources. On the service perspective, a service environment that can make full use of different abilities of different heterogeneous networks but in the meantime effectively screen the trivial details caused by heterogeneity will be the future trend of network development.

We need to explore highly efficient solutions in strategy management mechanism, connection control mechanism, switch mechanism, roaming mechanism and safety mechanism to construct a sound future network. In addition, we need to make further advancement in researches on the areas including network organizational behavior, network restructuring behavior and network resources distribution.

Today's mobile network and Internet system cannot meet people's needs for information exchange and intelligent services in the future. Researches based on user needs, which reexamine network and terminal's due functions and abilities to support services will exert far-reaching influence on future network structure design. Therefore, there is an urgent need to propose a forward-looking mobile Internet system to standardize the functions and characteristics of the next generation mobile Internet. It is needed to guide and regulate China's researches on some major fundamental issues about next generation mobile Internet in the first 20 years of the 21st century. Moreover, there is a need to study and conclude design principles of system structure and system design restraint, to figure out the interdependent relationship between basic theories and key technologies in the MUSE system structure. In addition, it work on interdependent relationship between MUSE system and other systems and their evolution strategy.

3 Concept of MUSE

3.1 Basic Concept

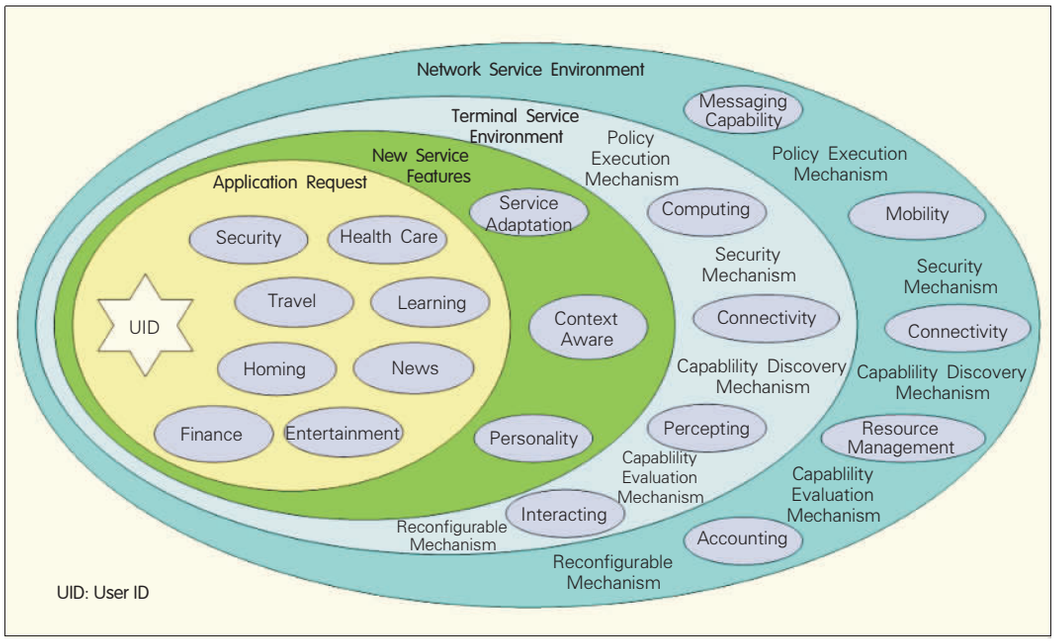
The network heterogeneity is more abundant in the future. The trend of more heterogeneity and diversity in terminal technology, network technology and service platform technology is as noticeable as that in wireless access. Diversity and heterogeneity in networking structures make people puzzled about the future trend of technological development.

The MUSE was introduced as a tentative description of the prospects and goals of the future wireless world. In MUSE, the telecommunications system can support varying degrees of mobile and seamless connections through coordinated work of each heterogeneous sub-network. Meanwhile, the ubiquitous intelligent terminal equipment and sensor network can fully exchange environment and context information, such as individual preferences, user's physical condition and emotion, temperature and humidity of surrounding environment, and support the integration of information and physical space. Coordination between the network and its ambient ubiquitous system can generate services that are more intelligent and provide users with ABE. While on the perspective of services, the MUSE can create a service development and deployment environment that is able to make full use of heterogeneity of different networks and at the same time avoid the trivial details of the networks. Therefore, it helps achieve the rapid development and deployment of services. All these can be concluded as offering abundant and suitable services. In a word, the core concept in MUSE is coordination and integration of networks and ubiquity and intelligence of terminals.

3.2 Model for Reference

Evolution of MUSE is illustrated in Figure 1. Figure 2 shows the model of MUSE from the user's perspective. The MUSE system mainly consists of three function factors: user, Terminal Service Environment (TSE), and Network Service Environment (NSE) and service.

User is represented by User ID (UID),



▲ Figure 2. Model of MUSE from the user's perspective.

which is the object of services offered by the whole MUSE system, a person or a group of persons who have ordered a series of specialized services and have their own preferences. A UID represents a real user, a group of users or cooperative users, or even a group of UIDs. One single user is allowed to own more than one UID.

The TSE is the terminal environment directly delivering services to users. It can be one set of terminal equipment with a series of network devices, or it can include ubiquitous intelligent devices that have been integrated to common environment. The TSE can provide services by coordinating its service abilities in different networks, and there are full interactions and adaptations between TSE, NSE and services through its responses to user's ambient environment and the context. That is, to provide user with more comfortable experience. It is easy to understand that the coordination of TSE and NSE as well as their mutual support is the sure guarantee for TSE to fully demonstrate its service ability. All these make user's personal information space further be integrated into the environment, make his/her life and work more harmonious and natural.

The NSE includes various heterogeneous networks, bridging TSE and services by coordination. In NSE, the heterogeneous networks are fully integrated with each other and they form a self–adapting, self–organizing and self–managing network environment with sound coordination. The NSE adjusts network environment according to context information and user preference given by TSE, effectively distributes cross–domain network resources and offers seamless network supports that bring ABE to the users. The NSE interacts and cooperates with a great number of typically self–organizing TSEs. The joint control and mutual support in different layers of the networks have created a huge space to provide abundant personalized services. Moreover, the NSE will offer an open platform to promote abundant services concentrating on the user.

Finally, the services are offered to users through MUSE. Through coordination and interaction of TSE and NSE, as well as user's personalized information, services finally bring ABE model to the users. In addition, the openness of MUSE brings in more freedom in offering services and that high quality services will be quickly and efficiently delivered to the users through MUSE's open service environment.

The accomplishment of MUSE prospect means the successful establishment of an intelligent telecommunications system that is based on users. The full coordination and cooperation between ubiquitous ambient devices and networks will bring diversified new services meeting different needs for people in the MUSE world, which means effective organization of cross–domain multi–layer systems and effective utilization of resources. People will emerge from different geographical, time and physical restraints that hamper people's communications, which will definitely provide people with extraordinary service enjoyment and thus improve people's style of life.

(to be continued)

Manuscript received: 2006–11–20

Biographies

Zhang Ping is a professor and a doctoral supervisor in Beijing University of Post & Telecommunications (BUPT). He is the Director of Wireless Technology Institute (WTI) of BUPT, Deputy Chairman of the Editorial Committee of BUPT Academic Journal, and member of Academic Committee of BUPT. He is also member of many important expert groups, such as China C3G Research Group, State "863" Future Mobile Telecommunications Project Group, WWRF and its Prospect Committee, and 3G Mobile Telecommunications Technology Laboratory under Ministry of Information Industry of China.

Ji Yang, Ph.D., is an associate professor with BUPT, the Deputy Director of WTI of BUPT and the Director of Service and Application Research Group of FUTURE Forum. His current direction for research is Beyond IMT2000 System, Network and Service Application.

Feng Zhiyong is an associate professor in BUPT and the Director of Network Department of WTI of BUPT. Her current direction for research is key technologies in future mobile ubiquitous network.